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Warner et al.

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(54) **AIRCRAFT SKIN SURFACE PLANING**

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B24B 19/26	(2006.01)
B24B 27/033	(2006.01)
B24B 19/00	(2006.01)

(52) **U.S. Cl.**

CPC ***B24B 19/005*** (2013.01); ***B24B 19/26*** (2013.01); ***B24B 23/02*** (2013.01); ***B24B 27/033*** (2013.01)

(58) **Field of Classification Search**

CPC B24B 23/00; B24B 23/02; B24B 19/26; B24B 27/033

USPC 451/358, 354, 352, 344, 28

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

851,702	A *	4/1907	Spietschka	30/476
915,080	A *	3/1909	Dixson et al.	30/477
1,540,591	A *	6/1925	Barker	451/358
2,136,529	A *	11/1938	Trimble	451/65
2,166,861	A	7/1939	Draheim	
2,277,236	A	3/1942	Kneisley et al.	
2,472,161	A *	6/1949	Godfried	451/352
2,625,860	A	1/1953	Plester	
2,987,970	A *	6/1961	Watson	409/181
3,421,411	A *	1/1969	Lowry et al.	409/143
3,456,555	A	7/1969	Dunlap	
3,705,448	A	12/1972	Bansen	
5,105,585	A	4/1992	Hampl et al.	
6,645,048	B1 *	11/2003	Linderholm et al.	451/28
6,929,436	B2 *	8/2005	Shannon	409/178
2003/0002946	A1	1/2003	Hsieh	

FOREIGN PATENT DOCUMENTS

DE	3831854	A1	4/1989
DE	9103187	U1	6/1991
WO	2012045912	A1	4/2012

OTHER PUBLICATIONS

European Search Report dated Oct. 24, 2014 for Application No. 14160094.0; Applicant: Lockheed Martin Corporation; 12 pages.

Partial European Search Report for Application No. 14160094.0-1709, dated Jul. 3, 2014; 8 pages.

* cited by examiner

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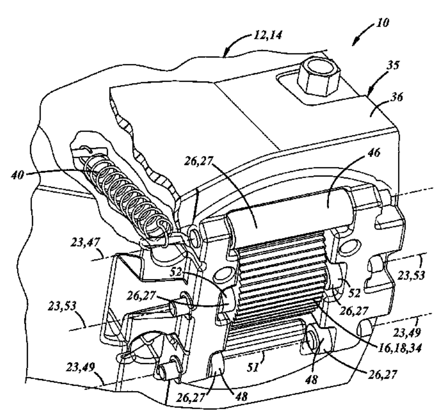
(57) **ABSTRACT**

A contoured surface planing apparatus for removing proud-standing material from a contoured surface without damaging the surface. The apparatus may include a tool comprising a motor-driven rotary cutter supported by a main body for rotation about a cutter axis, and orientation contact points spaced around the cutter and defining an orientation contact plane disposed parallel to the cutter axis.

16 Claims, 4 Drawing Sheets



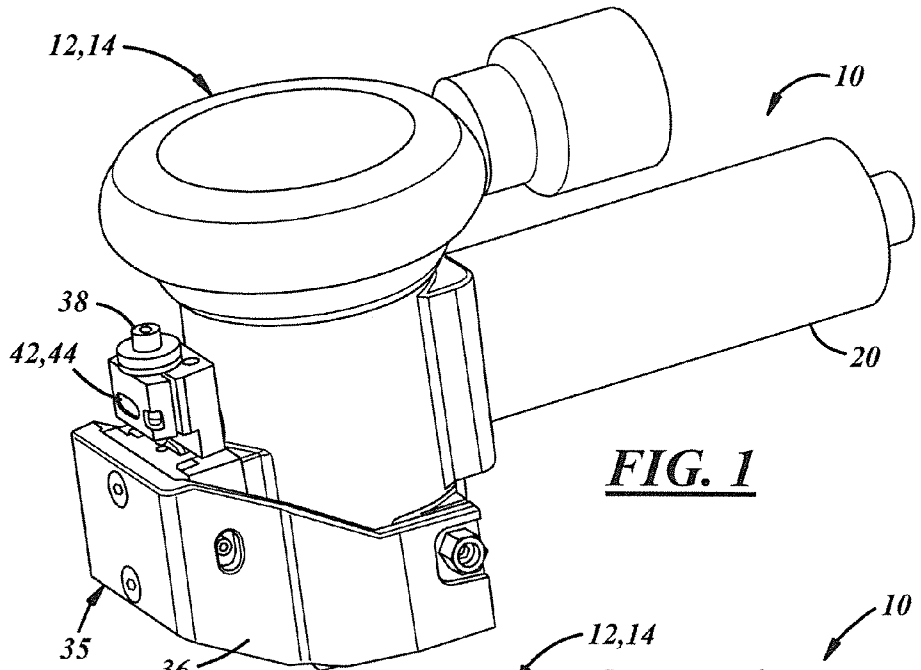

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FIG. 1

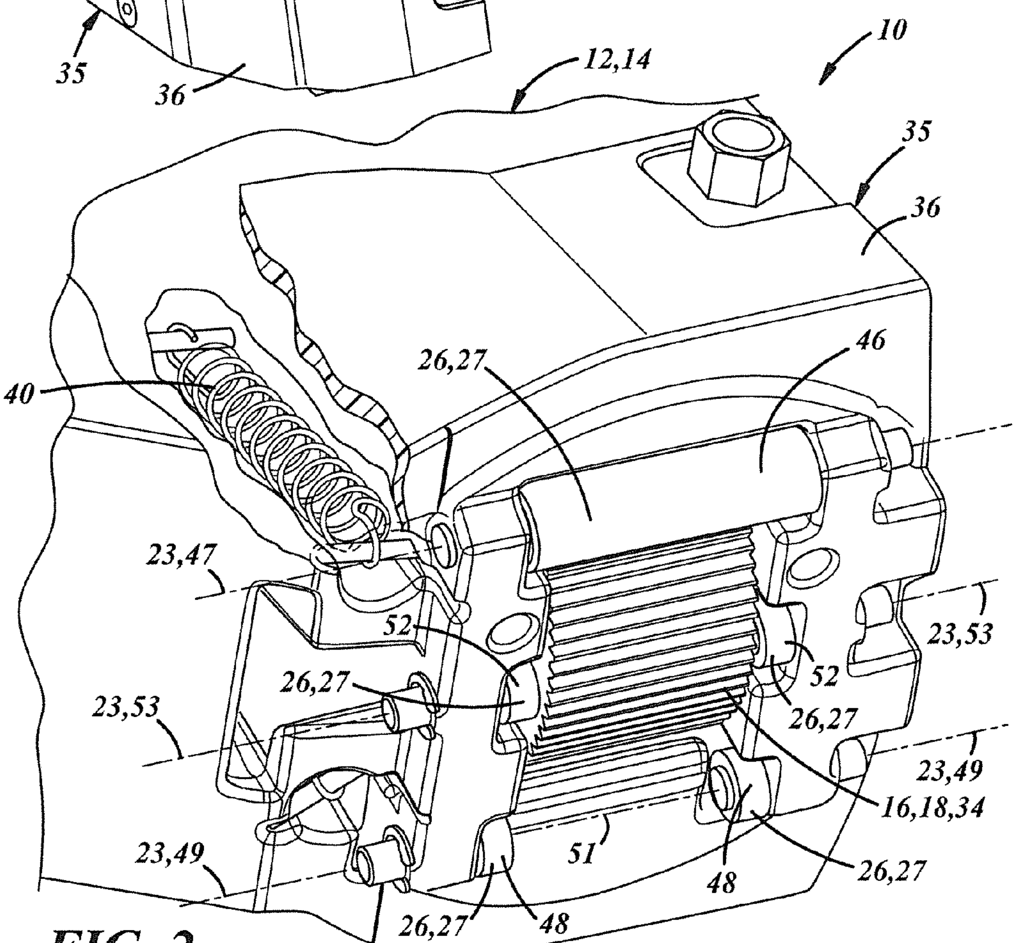
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FIG. 2

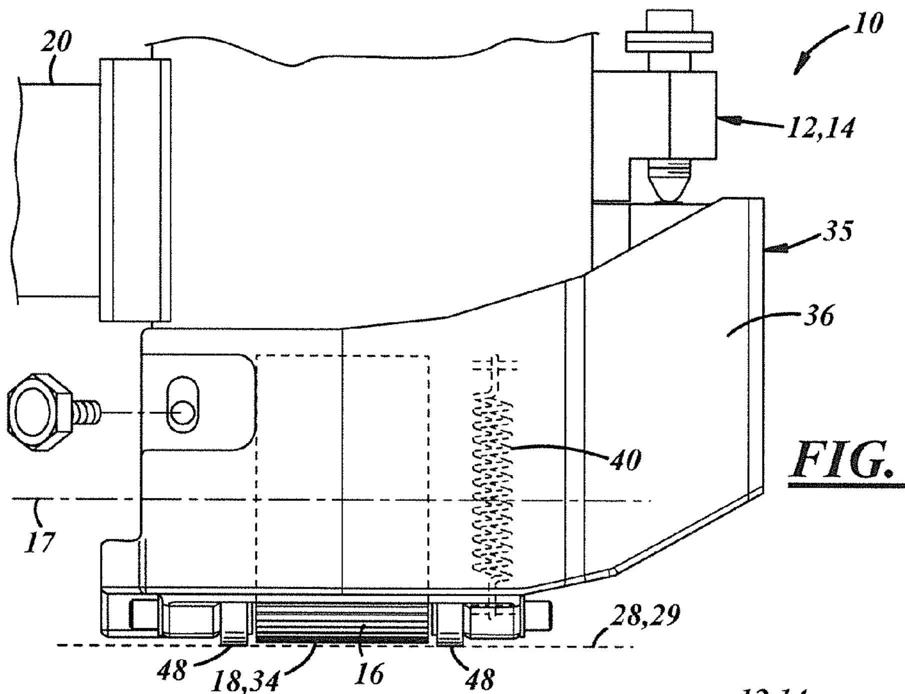

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FIG. 3

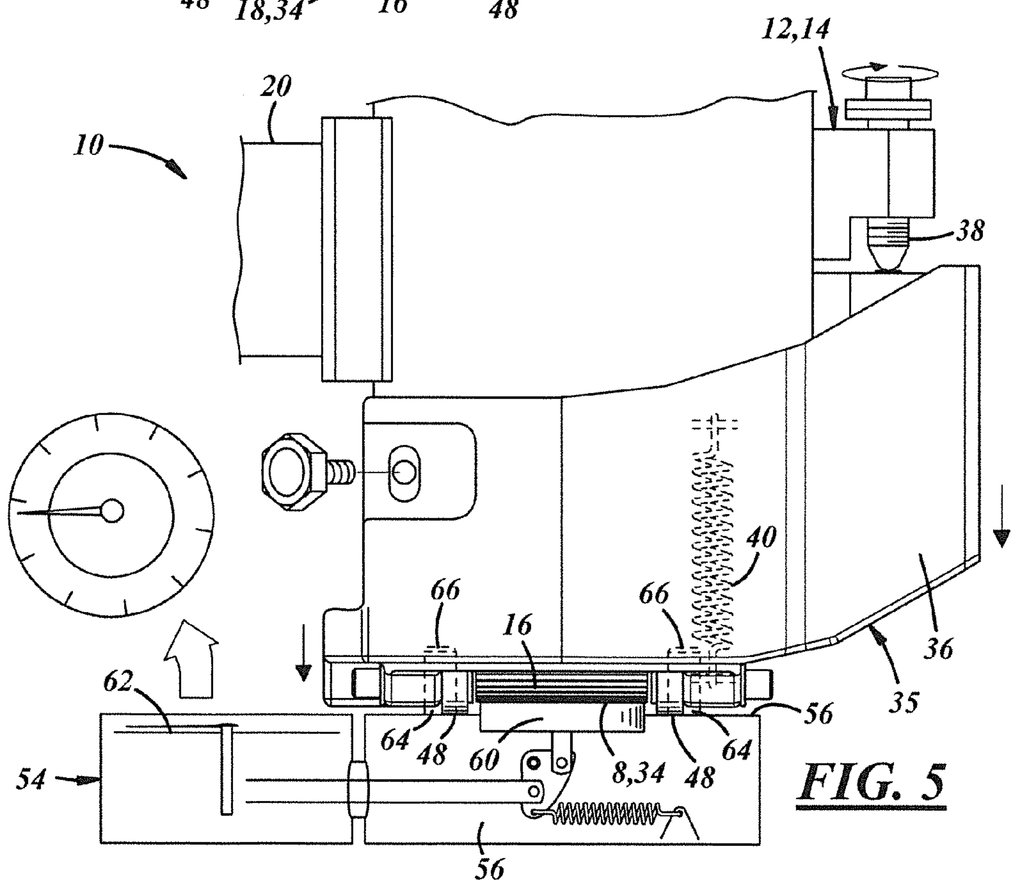

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FIG. 5

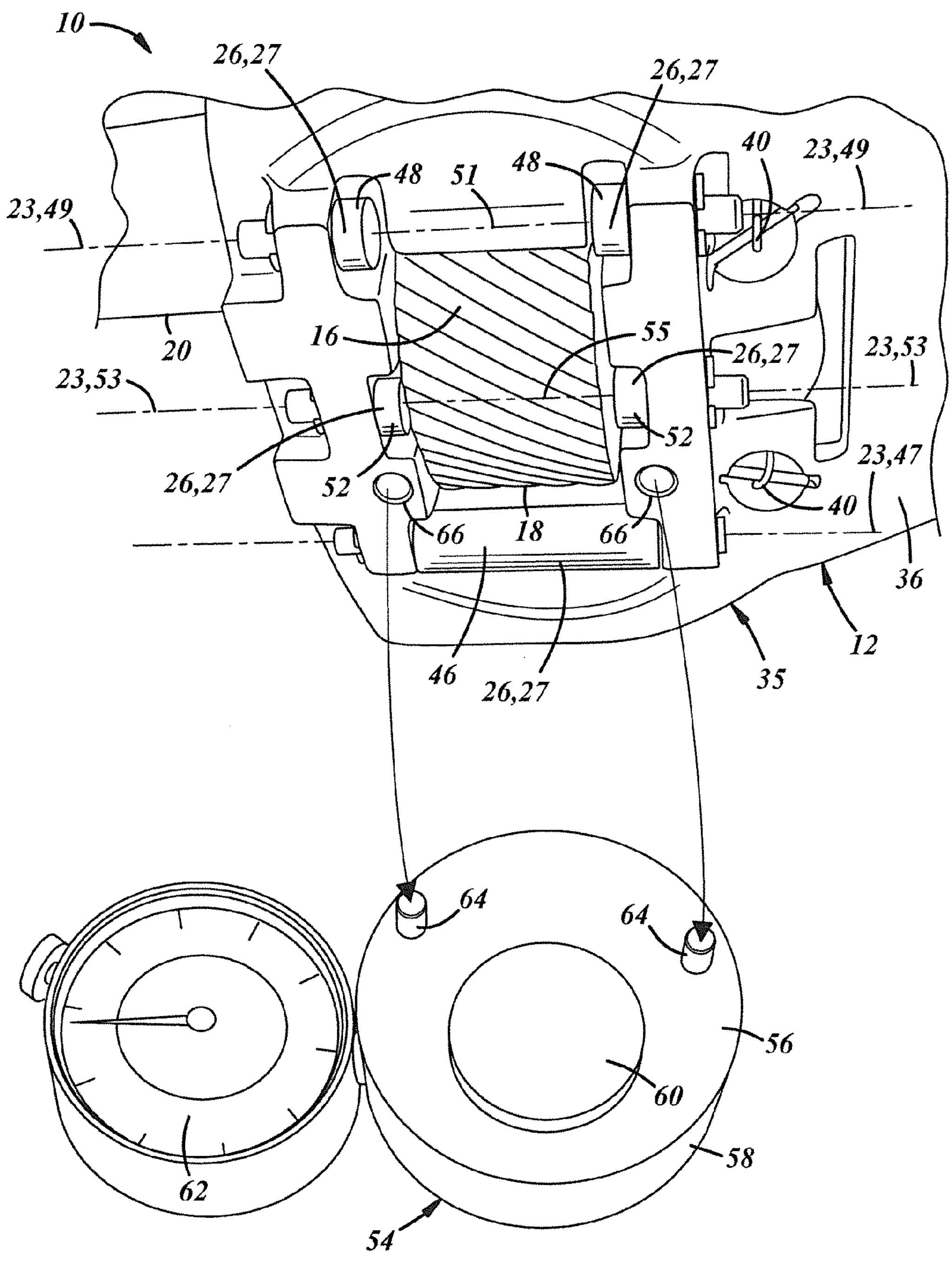
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FIG. 4

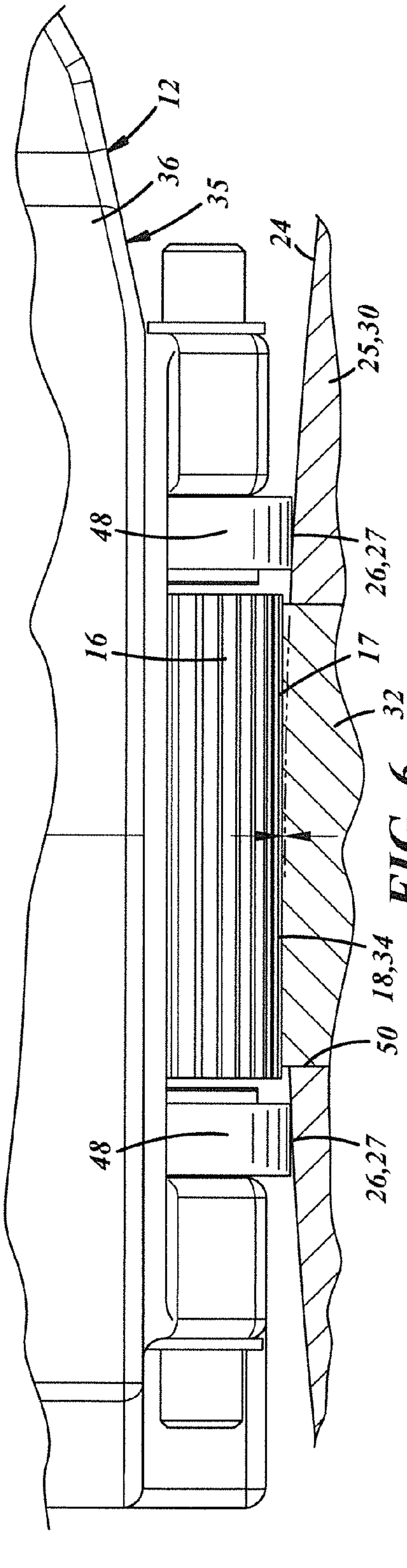
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FIG. 6

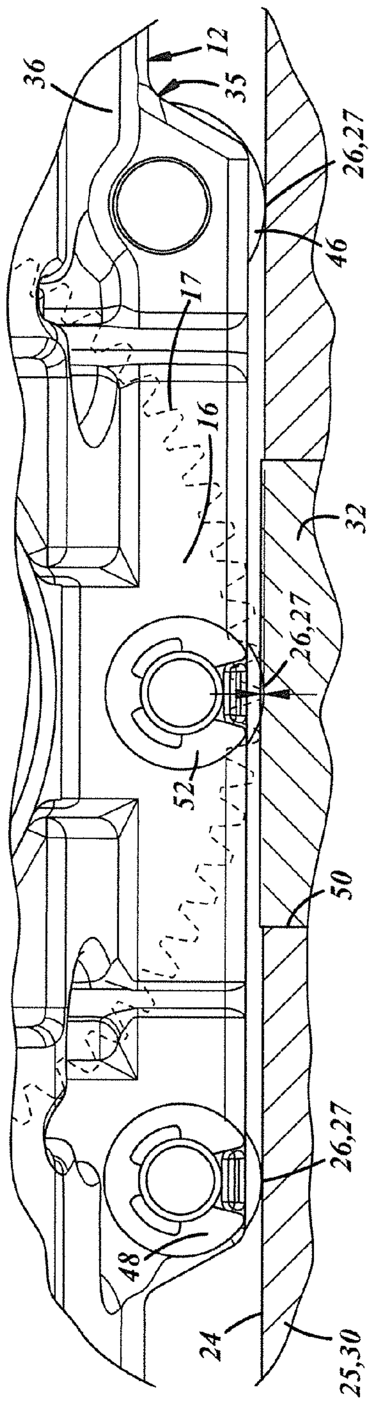
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FIG. 7

AIRCRAFT SKIN SURFACE PLANING

CROSS-REFERENCES TO RELATED APPLICATIONS

Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

BACKGROUND

1. Field

This application relates generally to the removal of excess material from a contoured surface, and may relate, more specifically to the removal of excess low-observable performance filler paste (LO filler) from over fastener holes in a composite aircraft skin panel.

2. Description of Related Art Including Information Disclosed Under 37 CFR 1.97 and 1.98

Low-observable performance material (LO filler) is applied as a filler paste over each of approximately 20,000 exterior fasteners on the F-35 aircraft. The application often leaves about 0.010"-0.020" of LO filler proud of the surface. To achieve desired low-observable characteristics it's desirable to remove enough of the excess LO filler so that an outer surface of remaining LO filler lies nearly flush with an outer surface of the skin panel (0.002-0.005" proud, depending on working surface contour curvature). Known methods of removing the excess LO filler include use of random orbital sanders, rough file, razor blades, and/or other manually driven hand tools. These methods have proven very time-consuming and exhausting and, when used without caution or skill, can result in damage to the composite skin surface surrounding the fasteners.

SUMMARY

A contoured surface planing apparatus is provided. The apparatus may comprise a tool including a main body, a rotary cutter supported by the main body for rotation about a cutter axis. The rotary cutter may comprise an abrasive outer circumferential cutter surface such as a routing surface. The tool may also include a motor operatively engageable with the cutter and configured to drive the cutter in rotation about the cutter axis, and at least three orientation contact points spaced around the cutter and defining an orientation contact plane disposed parallel to the cutter axis.

Also, a method is provided for removing proud-standing material from a contoured surface without damaging the surface. The method may include the steps of adjusting the distance between an orientation contact plane and a rotary abrasion contact region of a surface planing tool to a desired cutter displacement value, positioning the planing tool on a working surface with orientation contact points of the tool resting on the working surface, and reducing the height of proud-standing material by directing the tool along the working surface while maintaining the orientation contact points of the tool in contact with the working surface and while engaging the cutter with the proud-standing material.

DRAWINGS DESCRIPTIONS

These and other features and advantages will become apparent to those skilled in the art in connection with the following detailed description and drawings of one or more embodiments of the invention, in which:

FIG. **1** is an isometric view of a contoured surface planing apparatus;

FIG. **2** is a partial cross-sectional fragmentary bottom isometric view of the apparatus of FIG. **1** cut-away to show a spring connected between and biasing a chassis of the apparatus toward a base of the apparatus;

FIG. **3** is a fragmentary front view of the apparatus of FIG. **1**;

FIG. **4** is a fragmentary bottom view of the apparatus of FIG. **1** showing guide pin receptacles of the apparatus and a setup fixture having corresponding guide pins;

FIG. **5** is a fragmentary front view of the apparatus of FIG. **4** seated on the setup fixture of FIG. **4** with the guide pins of the setup fixture received in the guide pin receptacles of the apparatus;

FIG. **6** is a fragmentary front view of the apparatus of FIG. **1** showing rollers of the apparatus resting on an aircraft skin panel astride a fastener hole over-filled with LO filler, and with a rotary cutter of the apparatus shown engaging the LO filler; and

FIG. **7** is a fragmentary side view of the apparatus, aircraft skin panel, and over-filled fastener hole of FIG. **6**.

DETAILED DESCRIPTION

A contoured surface planing apparatus for removing proud-standing material from a contoured working surface, e.g., for removing excess low-observable performance filler paste (LO filler) from over fastener holes in a composite aircraft skin panel, and doing so without damaging the working surface, is generally shown at **10** in FIGS. **1-7**. As shown in FIG. **2**, the apparatus **10** may comprise a tool **12** including a main body **14** and a generally cylindrical or drum-shaped rotary carbide cutter **16** supported by the main body **14** for rotation about a cutter axis **17**. As best shown in FIG. **5**, the cutter **16** may comprise an abrasive outer circumferential serrated cutter surface **18** such as a routing surface, which is coaxially located with respect to the cutter axis **17**. As shown in FIG. **1**, a drill motor **20** may be carried by the main body **14** and connected to the cutter **16**. The drill motor **20** may be configured to drive the cutter **16** in rotation about the cutter axis **17**.

As best shown in FIG. **2**, the tool **12** may include at least three, and preferably five, rollers **46**, **48**, **52** supported on the base for rotation about respective roller axes **23**. The roller axes **23** may be disposed parallel to the cutter axis **17** and thus normal to an intended direction of cut so that the rollers **46**, **48**, **52** will be positioned to provide rolling contact with a working surface **24** in the intended direction of cut. The working surface **24** may be that of a workpiece **25** such as, for example, a composite F-35 skin panel.

The apparatus **10** may include orientation contact points **26** spaced around the cutter **16**. The orientation contact points **26** may define an orientation contact plane **28** (shown in FIG. **3**) disposed parallel to the cutter axis **17** so that orientation of the tool **12** with all orientation contact points **26** contacting a working surface **24**, as shown in FIGS. **6** and **7**, will also orient the rotational axis **17** of the cutter **16** parallel to a portion of the working surface **24** to be planed.

As shown in FIG. **7**, the contact points **26** may be respective rolling contact points **27** of the rollers **46**, **48**, **52**, (defined as the points where the rollers **46**, **48**, **52** contact the working surface **24** during a planing operation,) and the orientation contact plane **28** may thus be a rolling contact plane **29**, (i.e., a plane defined by the rolling contact points **27** of the rollers

46, **48**, **52**. In other words, the rolling contact point of each roller may be whatever portion of a circumferential outer rolling surface of the roller lies in the rolling contact plane,) and may be in rolling contact with a working surface **24** when the tool **12** is held in rolling contact with the working surface **24** during a planing operation. This planar roller arrangement prevents the cutter **16** from cutting too deeply and removing composite panel material **30** along with LO filler material **32** while passing over or riding along projecting contours in the working surface **24**.

As shown in FIG. **3**, the rolling contact plane **29** may be spaced from, and below, a rotary abrasion contact region **34** of the rotary cutter **16**. The rotary abrasion contact region **34** of the cutter **16** may be defined as whatever portion of the outer circumferential abrasive cutter surface **18** is closest to the rolling contact plane **29** at any given point in time. The rotary abrasion contact region **34** may thus be presented in a position for abrading contact with a mass of LO filler material **32** carried by and standing proud of a working surface **24**. The rolling contact plane **29** may also be spaced or displaced radially from the rotary abrasion contact region **34** by a cutter displacement value sufficient to protect protruding contours of a working surface **24** from abrading contact with the cutter **16** during a planing operation. This planar roller arrangement may thus prevent the cutter **16** from cutting too deeply and removing composite panel material **30** along with the LO filler material **32** while passing over or riding along projecting contours in the working surface **24**.

As shown in FIGS. **1-5**, the tool **12** may include a rolling foot **35**, which may comprise the rollers **46**, **48**, **52**, and a chassis **36** carried by the main body **14**, upon which the rollers **46**, **48**, **52** may be supported for rotation about their respective roller axes **23**. The chassis **36** may be supported on the main body **14** for reciprocal motion relative to the main body **14** so that the chassis **36** may be moved between fully extended and fully retracted positions to adjust cutter displacement, (i.e., the distance between the rolling contact plane **29** and the abrading contact region **34** of the cutter **16**,) allowing cutting depth to be adjusted to accommodate different working surface contour geometries.

The tool **12** may include a cutter displacement adjustment screw **38**, best shown in FIG. **3**, which may be threadedly engaged with the main body **14** to bear downward against the chassis **36**. As best shown in FIG. **2**, the tool **12** may further include a biasing element **40** supported between the chassis **36** and the main body **14** in a position to bias the chassis **36** upward against the adjustment screw **38** so that cutter displacement can be adjusted by turning the adjustment screw **38** to change the position of the chassis **36** relative to the main body **14** between the fully extended and fully retracted positions.

As shown in FIGS. **2**, **4**, and **7**, one of the rollers may be an elongated aft roller **46** supported on the chassis **36** for rotation about a aft roller axis **47** oriented parallel to the rolling contact plane **29**, parallel to the cutter axis **17**, and centered on and spaced behind the cutter **16** relative to the intended direction of cut. The elongated aft roller **46** may have an axial length greater than or equal to an axial length of the outer circumferential cutter surface **18** to ensure that the cutter **16** does not cut into contours of a working surface **24** while removing excess LO filler **32**. In the present embodiment, the cutter **16** and the abrading contact region **34** of the cutter **16** may have an axial length of 0.75". This should allow the tool **12** to be used on a compound curved working surface having a 30" radius one direction and a 100" radius in the other without damaging the surface. However, in other embodiments, any suitable length of aft roller **46** or cutter **16** may be used to adapt the tool **12** to work on differently-curved surfaces. In other embodiments, the aft roller **46** may comprise multiple rollers or rolling elements rather than a single roller.

Two of the rollers may be 0.25" wide leading rollers **48** supported on the chassis **36** for rotation about respective leading roller axes **49**. The leading roller axes **49** may be coaxially disposed along a common leading roller axis **51** parallel to the cutter axis **17** and spaced ahead of the cutter **16** relative to the intended direction of cut. The leading rollers **48** may be centered on the cutter **16**, and may be spaced axially from one another by a distance approximately equal to the axial length of the outer circumferential cutter surface **18**. The leading rollers **48** may thus be spaced to bridge a region of the working surface **24** to be cut, allowing the tool **12** to be run along a row of LO paste-filled fastener holes **50** while straddling patches of excess LO filler **32** to be removed from over the holes **50**.

Two of the rollers may be 0.25" wide side mid rollers **52** supported on the chassis **36** for rotation about respective mid roller axes. The mid roller axes **53** may be coaxially disposed along a common mid roller axis **55**. The mid roller axes **53** may be parallel to the cutter axis **17** and disposed between the cutter axis **17** and the rotary abrasion contact region **34** of the rotary cutter **16** to ensure that the rotary abrasion contact region **34** remains spaced from the rolling contact plane **29**. To reduce curvature issues the mid rollers **52** may be disposed as close as practical to the cutter **16**.

As shown in FIGS. **4** and **5**, the apparatus **10** may include a setup fixture **54** comprising a support surface **56** carried by a fixture base **58**. The support surface **56** may be configured to support the tool **12** with the orientation contact points **26** (e.g., the rollers **46**, **48**, **52**) of the tool **12** resting on the support surface **56**. A cutter contact element **60** may also be carried by the fixture base **58**, and may be biased upward relative to the support surface **56** to maintain contact with the cutter **16** during cutter displacement adjustment. A gage **62** may be connected to the cutter contact element **60** and configured to measure cutter displacement by measuring cutter contact element displacement relative to the support surface **56**. The gage **62** may also be configured to show an operator a visual representation of the magnitude of cutter displacement when the tool **12** is resting on the support surface. The setup fixture **54** may be, for example, a 0.0005" graduation zero-setter gage such as is manufactured by the Mitutoyo Corporation.

As best shown in FIG. **4**, the setup fixture **54** may include two parallel guide pins **64**, and the tool **12** may include two parallel guide pin receptacles **66** positioned and configured to receive the guide pins **64** when the tool **12** is mounted on the setup fixture **54**. The guide pins **64** and receptacles **66** may be arranged to positively position the tool **12** such that the cutter **16** rests on the cutter contact element **60** and the orientation contact points **26** (e.g., the rollers **46**, **48**, **52**) rest on the support surface **56**.

In practice, excess material, such as excess LO filler **32**, may be removed from a contoured working surface, such as from over fastener holes **50** in a composite F-35 skin panel, without damaging the working surface, by first mounting the tool **12** on a support surface **56** of a setup fixture **54** such that the orientation contact points **26** of the tool rest on the support surface **56** of the fixture, the rotary cutter **16** of the tool rests on a cutter contact element **60** of the fixture **54**, and such that a gage **62** connected to the cutter contact element **60** displays a numerical cutter displacement value, i.e., a value representing the distance between the rotary abrasion contact region **34** and the orientation contact plane **28** of the tool **12**. Cutter displacement may then be adjusted until a desired cutter displacement value of, for example, 0.003 inches is displayed on the gage **62** by turning a cutter displacement adjustment screw **38**. The planing tool **12** may then be positioned on a working surface **24** adjacent a mass of LO filler material **32** standing proud of the working surface **24** and the tool **12** oriented such that the contact points **26** of the tool rest on the working surface **24**.

The height of the proud-standing LO filler material **32** may then be reduced by directing the tool **12** along the working surface **24** while maintaining the orientation contact points **26** of the tool **12** in contact with the working surface **24**, and engaging the cutter **16** with the LO filler material **32**. To engage the LO filler material **32**, the planing tool **12** may be directed in a desired cut direction such that the pair of leading rollers **48** and the pair of mid rollers **52** roll with their axes **49**, **53** oriented perpendicular to the cut direction and straddle the LO filler material **32** while the cutter **16** is moved to engage the proud-standing LO filler material **32**. The planing tool **12** may also be directed such that the elongated aft roller **46** rolls behind the cutter **16** with the axis of the aft roller **46** oriented perpendicular to the cut direction and parallel to the orientation contact plane **28**.

A contoured surface planing apparatus constructed as described above allows excess LO filler paste to be quickly removed from fastener holes in composite aircraft skin panels with minimum manual effort, and without danger of causing damage to the aircraft skin. The device may remove enough excess LO filler so that an outer surface of the remaining LO filler lies nearly flush (0.002-0.005" proud, depending on contour curvature) with an outer surface of the skin panel. Use of a setup fixture such as the described zero-setter allows the tool to be accurately configured for each use, even in cases where extended use has worn down the cutter surface.

This description, rather than describing limitations of an invention, only illustrates an embodiment of the invention recited in the claims. The language of this description is therefore exclusively descriptive and is non-limiting. Obviously, it's possible to modify this invention from what the description teaches. Within the scope of the claims, one may practice the invention other than as described above.

What is claimed is:

1. A contoured surface planing apparatus comprising a tool including:

- a main body;
- a rotary cutter supported by the main body for rotation about a cutter axis and comprising an abrasive outer circumferential cutter surface;
- a motor operatively engageable with the cutter and configured to drive the cutter in rotation about the cutter axis;
- at least three rollers supported on the base and having rolling contact points spaced around the cutter and defining rolling contact plane disposed parallel to the cutter axis, at least two of the rollers being leading rollers disposed forward of the cutter, and one of the rollers being an aft roller disposed aft of and in alignment with the cutter relative to an intended direction of cut.

2. A contoured surface planing apparatus as defined in claim **1** in which the rollers are wheels supported on the base for rotation about respective roller axes disposed parallel to the cutter axis and normal to an intended direction of cut.

3. A contoured surface planing apparatus as defined in claim **1** in which the tool includes a rolling foot comprising the rollers and a chassis carried by the main body and upon which the rollers are supported for rotation, the position of the rolling foot being supported on the main body for reciprocal motion relative to the main body between fully extended and fully retracted positions to adjust cutter displacement.

4. A contoured surface planing apparatus as defined in claim **3** in which the tool includes a cutter displacement adjustment screw threadedly engaged with the main body and bearing downward against the chassis, and the tool further includes a biasing element supported between the chassis and the main body in a position to bias the rolling foot upward against the adjustment screw.

5. A contoured surface planing apparatus as defined in claim **1** in which the aft roller comprises an elongated rolling element supported on the base for rotation about an aft roller axis oriented parallel to the rolling contact plane and spaced behind the cutter relative to the intended direction of cut.

6. A contoured surface planing apparatus as defined in claim **4** in which the aft roller axis is oriented parallel to the cutter axis.

7. A contoured surface planing apparatus as defined in claim **1** in which the aft roller spans an axial length greater than or equal to an axial length of the outer circumferential cutter surface.

8. A contoured surface planing apparatus as defined in claim **7** in which the axial length of the aft roller is as at least as long as an axial length of the outer circumferential cutter surface.

9. A contoured surface planing apparatus as defined in claim **1** in which two of the rollers are side mid rollers supported on the base for rotation about respective mid roller axes, the roller axes being parallel to the cutter axis and disposed between the cutter axis and the rotary abrasion contact region of the rotary cutter.

10. A contoured surface planing apparatus comprising a tool including:

- a main body;
- a rotary cutter supported by the main body for rotation about a cutter axis and comprising an abrasive outer circumferential cutter surface;
- a motor operatively engageable with the cutter and configured to drive the cutter in rotation about the cutter axis;
- at least three orientation contact points spaced around the cutter and defining an orientation contact plane disposed parallel to the cutter axis;

the apparatus further including a setup fixture comprising:

- a support surface;
- a cutter contact element biased upward relative to the support surface; and
- a gage connected to the cutter contact element and configured to measure cutter displacement by measuring cutter contact element displacement relative to the support surface and to display a visual representation of the magnitude of cutter displacement when the tool is resting on the support surface.

11. A contoured surface planing apparatus as defined in claim **10** in which one of the tool and setup fixture includes a guide pin and the other of the tool and setup fixture includes a guide pin receptacle positioned and configured to receive the guide pin when the tool is mounted on the setup fixture.

12. A contoured surface planing apparatus as defined in claim **11** in which the setup fixture includes two parallel guide pins extending from spaced apart locations on the support surface, and the tool includes two parallel guide pin receptacles positioned to receive the guide pins when the tool is placed on the setup fixture.

13. A method for removing proud-standing material from a contoured surface without damaging the surface, the method including the steps of:

- adjusting to a desired cutter displacement value the distance between an orientation contact plane and a rotary abrasion contact region of a surface planing tool, by mounting the tool on a support surface of a setup fixture such that orientation contact points of the tool are resting on a support surface of the fixture, a rotary cutter of the tool is resting on a cutter contact element of the fixture, and a gage connected to the cutter contact element is displaying a numerical value representing the distance between the rotary abrasion contact region and the orientation contact plane of the tool;

positioning the planing tool on a working surface with orientation contact points of the tool resting on the working surface;

reducing the height of proud-standing material on the working surface by directing the tool along the working surface while maintaining the orientation contact points of the tool in contact with the working surface and while engaging the cutter with the proud-standing material.

14. The method of claim **13** in which the adjusting step includes adjusting cutter displacement until the gage is displaying a desired cutter displacement value.

15. The method of claim **13**

in which:

the tool includes a pair of leading rollers supported for rotation about respective axes and defining two of the orientation contact points of the tool; and

the reducing step includes directing the planing tool in a desired cut direction with axes of the leading rollers oriented perpendicular to the cut direction and with the leading rollers straddling the proud-standing material as the cutter engages the proud-standing material.

16. The method of claim **15** in which:

the tool includes an aft roller supported on the tool chassis for rotation about an aft roller axis and defining another of the orientation contact points of the tool; and

the reducing step includes directing the planing tool such that the aft roller rolls trailing the cutter with the cutter and aft roller axes oriented perpendicular to the desired cut direction and parallel to the orientation contact plane.

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